

Teaching the History of Microbiology and the Transformation of the Laboratory: A Study in Miniature

Linda S. Guthertz

Office of the State Laboratory Director, California Department of Public Health, Richmond, CA 94804

This article presents a technique for bringing the history of microbiology to life in an exciting way. Eight miniature models were created, based on photographs or drawings, showing scientists at work in their labs. The models chosen represent important discoveries in microbiology, illustrating changes and advances in techniques and tools over the history of the discipline from 1600 through 2000. They serve as a novel and engaging teaching tool. While the instructor still presents the historic facts, the use of models provides the feeling of being there! They can also serve as a record for the future.

On the use of models as props

Nearly every introductory course in microbiology begins by paying homage to the experiments and achievements of the scientists who have come before us, beginning with the work of Girolamo Fracastoro in 1546. If we have reached a particular level of understanding since then, it is due to the discoveries and advances made by scientists following their passions. From the microscope that allowed Antony van Leeuwenhoek to see “little animalcules” for the first time to the biological safety measures used in labs today, new technologies and techniques that advance the field are the common thread running through the history of microbiology.

As compelling as stories of discovery and change may be for some learners, others view them as boring, difficult to visualize, and a waste of teaching time. It is a challenge for teachers to make a discussion of the history and development of science so exciting that it sparks the student's interest. Instructors have gone so far as to dress in costume as the scientists whose experiments they were presenting. An exciting introduction to microbiology can inspire a student to change his or her college major! It was Louis Pasteur who said, “There is in youth an unforgettable day that lights up all the rest of our lives. That is the day when we meet those teachers to whom we owe our first enthusiasm. Ah, what other moment, what fortune of our careers can ever be worth as much as that moment” (3).

One particular way of bringing excitement and energy to the classroom dates back to the 1940s. Frances Glessner Lee—who endowed the Department of Legal Medicine and later established the George Burgess Magrath Library of Legal Medicine at Harvard University—began a series of seminars where participants spent a week learning the art of crime scene investigation (1). The collection of material evidence at a crime scene can be overwhelming. Lee believed that with knowledge of forensics and collection techniques, one could be trained to collect evidence systematically. Yet such hands-on training for police officers, medical examiners, and others was virtually impossible due to privacy issues, the time needed, and the timing. After all, who could predict that a crime might occur during the course of the seminar series? This led Lee to construct 20 miniature crime scenes as teaching tools, used to demonstrate how the observation of important details and evidence could affect the outcome of investigations. She named the models The Nutshell Studies of Unexplained Death.

Frances Glessner Lee's models led me to conclude that miniature scenes depicting laboratory settings would be unique props that could help teach the history of microbiology in an exciting way. Tamari, Bonney, and Polizzotto's article on the use of prop demonstrations to facilitate student learning and performance convinced me that this was a viable teaching technique (2), and I began to develop lectures incorporating prop demonstrations on the transformation of the microbiology laboratory from 1600 to 2000.

The models: miniature laboratories

The microbiology laboratory is continually changing and rapidly advancing. Along with primers and probes used in PCR, there is now culture-independent diagnostic testing, digital microbiology, smart incubators, and even whole genome sequencing! It is clear that, within a few years, the

Corresponding author. Mailing address: Office of the State Laboratory Director, California Department of Public Health, 850 Marina Bay Parkway, Richmond, CA 94804. Phone: 510-307-8922. E-mail: linda.guthertz@cdph.ca.gov.

Received: 10 November 2016, Accepted: 26 January 2017, Published: 21 April 2017.

microbiology laboratory will look nothing like it does today, just as our labs bear little resemblance to those of our predecessors Louis Pasteur and Robert Koch.

Louis Pasteur said “Take interest, I implore you, in those sacred dwellings which are designated by the expression term, laboratories. Demand that they be multiplied and advanced. These are the temples of the future, temples of well-being and happiness ... where humanity grows greater, stronger, better” (3). This quotation helped me decide to create models of eight laboratories in which important discoveries in microbiology occurred between 1673 and 2000. Created on the scale of 1:12, these models bring to life the laboratories of Antony van Leeuwenhoek, Louis Pasteur, Robert Koch, Rosalind Franklin, Selman Waksman, Paul Ehrlich, and Sir Alexander Fleming, as well as the Microbial Diseases Laboratory (MDL) of the California Department of Public Health (see Figs. 1–6). The selected scientists and laboratories were reproduced from pictures. Each laboratory—a snapshot in time—was displayed on a box containing one or more books about the scientist and the work depicted in the model (see Table I for a list of the books).

Use of the models in graduate instruction

As Oren has suggested, these laboratory re-creations can be used to bring life and excitement to humanities and social sciences majors learning about microbiology

to fulfill a science requirement (4). I propose that these models also have a use in graduate instruction. My current teaching responsibility is to prepare college graduates for the California Public Health Microbiologist certification examination through a six-month laboratory training



FIGURE 1b. Leeuwenhoek using his microscope.



FIGURE 1a. The Delft laboratory of Antony van Leeuwenhoek.

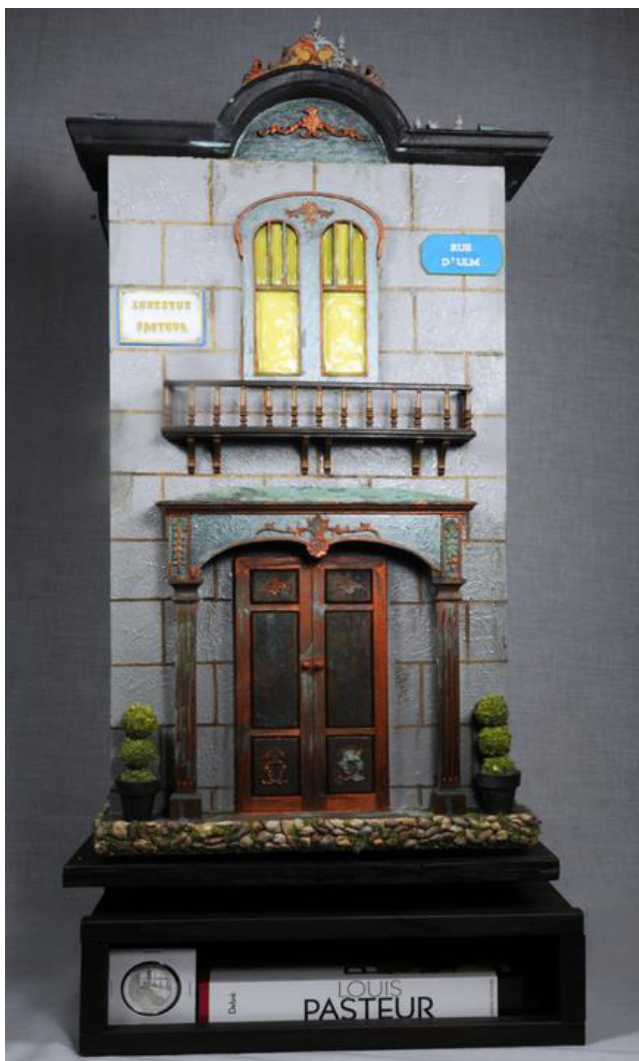


FIGURE 2a. Rue d'Ulm laboratory of Louis Pasteur.

course in the various microbiology disciplines. There are 23 units in this training program.

While many of my current students have a strong background in molecular techniques, I have found that they have little knowledge of the history and development of the science of microbiology. In my courses, I use these models to provide historical background and generate brief discussions of the controversies which surrounded some discoveries. Table 2 indicates which model is used to introduce each training unit. For example, the model of Louis Pasteur's laboratory shows him examining swan-neck flasks for growth (Fig. 2b) and serves to launch a discussion of the disproval of the theory of spontaneous generation.

The models serve as valuable visual aids and discussion prompts. The students have been fascinated with the models as well as the science behind them. As time allows, they are permitted to borrow the books to further investigate the scientist of their choice. Additionally, I show historical



FIGURE 2b. Pasteur examining his swan-neck flasks for microbial growth.



FIGURE 2c. Dr. Emile Roux working on the development of rabies treatment using the desiccated spinal cords of rabbits.



FIGURE 3a. Laboratory of Robert Koch showing use of laboratory animals and beginnings of photomicrography.

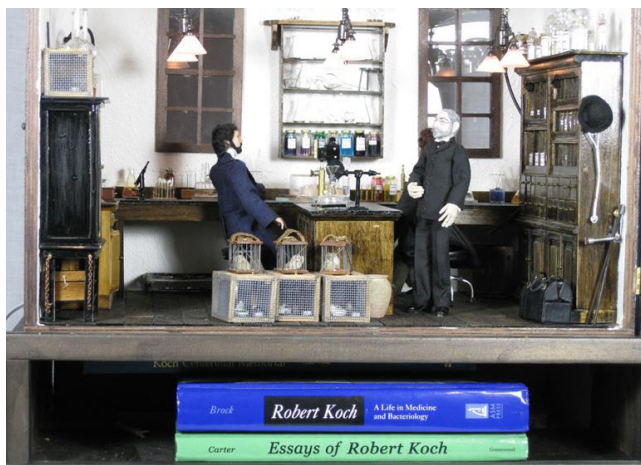


FIGURE 3b. Laboratory of Robert Koch showing first usage of water baths, incubators, and petri dishes.



FIGURE 4. Laboratory of Rosalind Franklin showing X-ray crystallography equipment. Shows a discussion on the shape of the DNA molecule with Watson, Crick, Gosling, and Wilkins.

movies such as *The Story of Louis Pasteur* and *Dr. Ehrlich's Magic Bullet* during the lunch hour.

The models, from past to present

The scientists and laboratories re-created in the models illustrate how scientific knowledge has been advanced by the discovery, development, and dissemination of new technical methods. The people and places featured, in chronological order, are as follows:



FIGURE 5a. Entrance to California Department of Public Health.



FIGURE 5b. Microbial Diseases Laboratory building.

Antony van Leeuwenhoek: Zacharias Jansen and his father Hans are credited with making the first compound microscope in the late 16th century. These Dutch spectacle makers produced an instrument capable of magnifying images three to ten times (5). Yet it was the single-lens system of Antony van Leeuwenhoek that enabled the first ever view of bacteria. Could microbiology have been born without the advent of Leeuwenhoek microscopes? Probably not. Figures 1a and 1b show the model of Leeuwenhoek's Delft linen shop, with the man himself examining specimens with his microscopes. Antony van Leeuwenhoek's microscope was able to confirm what others had hypothesized: the existence of minute living organisms that the unaided eye is unable to see.

Louis Pasteur: Louis Pasteur's work on fermentation in the 1850s and 60s landed him in the middle of the controversy surrounding spontaneous generation (6). Pasteur challenged this doctrine with his ingenious experiments: He showed that if air was prevented from entering a flask of nutrient broth, the broth remained pure. If those same flasks



FIGURE 5c. Enterics Laboratory Unit.



FIGURE 5d. Laboratory benchtop showing cultures and slides used in bacterial identification.



FIGURE 5e. Laboratory carts with cultures to be taken to workstations.



FIGURE 6. Present-day laboratory items in miniature.

were exposed to air or to a drop of water teeming with organisms, the organisms would grow. Pasteur's discovery that life is not generated spontaneously, combined with van Leeuwenhoek's confirmation of the existence of bacteria, sparked years of scientific discovery and laboratory changes in the science of bacteriology. Pasteur's singular experiment was so important that it was the second miniature laboratory created. In Figure 2b, Pasteur is seen examining his swan-neck flasks, while his associate Dr. Emile Roux works on the rabies treatment with desiccated spinal cords from rabbits in Figure 2c. The painstaking methods used by Pasteur and his associates clearly illustrate the need for, and value of, tools to work with bacterial organisms in the laboratory.

Robert Koch: Robert Koch did important work with *Bacillus anthracis*, *Mycobacterium tuberculosis* and *Vibrio cholerae*. Many of the tools used to work with bacteria, and which are still in use today, were developed in his laboratory (7). In Figures 3a and 3b, we see my version of Koch's laboratory, which is based on one existing drawing that shows him working with his staff scientists between 1885 and 1890. Careful examination of this model reveals water baths, incubators, petri dishes and solidified media—all of which were first used in Koch's laboratory—as well as the first attempts at taking photomicrographs and experimental

animal work. Koch's development of these tools had to be intimately involved with the development of his postulates (8).

Selman Waksman and Alexander Fleming: The discovery of antibiotics changed human life as well as the microbiology laboratory. I selected the laboratories of Alexander Fleming and Selman Waksman with Albert Schatz to demonstrate this period of history. After Fleming's discovery of penicillin, Waksman's discovery of streptomycin and work with fungi and actinomycetes led to a new microbiological era in which diseases became treatable. New antibiotics were discovered, and tests were developed to determine which antibiotic could be used against a particular pathogenic organism. Bacteriology flourished for the next 100 years: more than 10,000 named bacterial species were discovered, the relationship of these organisms to disease was uncovered, and tools for their study were developed.

Rosalind Franklin: The era of DNA—its chemistry, its structure, and the process of carrying and transmitting genetic material—came next. To bring this era to life, the laboratory of Rosalind Franklin was built (Fig. 4). In it, Franklin and Raymond Gosling are meeting with Maurice Wilkins, James D. Watson, and Francis Crick. The revelation of the structure of DNA and the development of the PCR technique by Kary Mullis have forever changed the microbiology laboratory.

Microbial Diseases Laboratory, California Department of Public Health: What would become the Microbial Diseases Laboratory (MDL) of the California Department of Public Health was founded in 1905 during an outbreak of plague (9). This laboratory was the beginning of the California Public Health laboratory system. Dr. Kimsey, State Laboratory Director, noted that while science today is far more complex than it was in the 1900s, we owe much of the progress made to the contributions of public health laboratories (9).

Until recently, the MDL consisted of six sections: Special Bacteriology, Enterics and Parasitology, Mycobacteriology and Mycology, Serology, and Biologics and Environmental Microbiology. I selected the Enterics Laboratory of MDL (Figs. 5a–5c) to illustrate the type of laboratory which has existed from the early 1900s until recently. The molecular age has resulted in a renaissance with respect to laboratory design, equipment, and testing methods. Along with the use of test tubes and a variety of bacteriologic media (Figs. 5c–5e), this model shows other tools from the beginning of the molecular age: Pulsed Field Gel Electrophoresis, advances in safety through the use of a biological safety cabinet, advances in microscopy, and the use of computers.

The models: a teaching tool and a record

The evolution of molecular techniques and mechanization have changed the microbiology laboratory. Models

GUTHERTZ: USING MINIATURES TO TEACH HISTORY

TABLE I.
Reading material supplied with miniature reproductions.

Laboratory Reproduction	Reading Material Provided with Model
Antony van Leeuwenhoek	Dobell, C. 1958. <i>Antony van Leeuwenhoek and His "Little Animals."</i> Russell & Russell, Inc., New York. 435 pp
Louis Pasteur	Vallery-Radot, R. 1916. <i>The Life of Pasteur.</i> Translated by R. L. Devonshire. Doubleday, Page & Co., New York. 484 pp Debré, P. 1994. <i>Louis Pasteur.</i> Johns Hopkins University Press, Baltimore, MD, and London. 552 pp
Robert Koch	Koch, R. <i>Essays of Robert Koch.</i> Translated by K. Codell Carter. 1987. Greenwood Press, New York. 189 pp Brock, T. D. 1999. <i>Robert Koch: A Life in Medicine and Bacteriology.</i> ASM Press, Washington, DC. 364 pp Wilmot, C. B, T. M. Daniel, and G. M. Green. 1982. <i>Koch Centennial Memorial.</i> American Lung Association, New York. 132 pp
Paul Ehrlich	Silverstein, A. M. 2002. <i>Paul Ehrlich's Receptor Immunology: The Magnificent Obsession.</i> Academic Press, New York. 202 pp Baumler, E. 1984. <i>Paul Ehrlich: Scientist for Life.</i> Holmes and Meier, New York. 288 pp
Rosalind Franklin	Sayre, A. 1975. <i>Rosalind Franklin and DNA.</i> W.W. Norton & Co., Inc., New York. 221 pp Maddox, B. 2002. <i>Rosalind Franklin: The Dark Lady of DNA.</i> Perennial. 380 pp Franklin, R. E. and R. G. Gosling. 1953. Molecular configuration in sodium thymonucleate. <i>Nature</i> 171:740–741. Watson, J. D. and F. H. C. Crick. 1953. Molecular structure of deoxyribose nucleic acid. <i>Nature</i> 171:737–738. Wilkins, M. H. F., A. R. Stokes and H. R. Wilson. 1953. Molecular structure of deoxypentose nucleic acids. <i>Nature</i> 171:738–740. Watson, J. D. and F. H. C. Crick. 1953. Genetical implications of the structure of deoxyribonucleic acid. <i>Nature</i> 171:964–967. Franklin, R. E. and R. G. Gosling. 1953. Evidence for a 2-chain helix in crystalline structure of sodium deoxyribonucleate. <i>Nature</i> 172:156–157.
Selman Waksman	Waksman, S. A. 1958. <i>My Life with the Microbes.</i> The Scientific Bookclub. Northumberland Press Ltd. Gateshead on Tyne. 320 pp Pringle, P. 2012. <i>Experiment Eleven: Dark Secrets Behind the Discovery of a Wonder Drug.</i> Walker & Co, New York. 278 pp Auerbacher, I. and A. Schatz. 2006. <i>Finding Dr. Schatz: The Discovery of Streptomycin and a Life it Saved.</i> iUniverse. 142 pp
Sir Alexander Fleming	Birch, B. 1990. <i>Alexander Fleming.</i> Irwin Publishing, Toronto. 64 pp Fleming, A. 1946. <i>Chemotherapy: Yesterday, To-day and To-morrow.</i> The Linacre Lecture. Cambridge University Press. 89 pp Lax, E. 2005. <i>The Mold in Dr. Florey's Coat: The Story of the Penicillin Miracle.</i> Henry Holt & Co., New York. 307 pp Brown, K. 2004. <i>Penicillin Man: Alexander Fleming and the Antibiotic Revolution.</i> Sutton Publishing. 353 pp
California Department of Public Health	Janda, J. M. and S. L. Abbott. 2006. <i>The Enterobacteria.</i> 2nd ed. ASM Press, Washington, DC. 411 pp

TABLE 2.
Models used with training units.

Training Unit	Model Used
Introduction	Louis Pasteur
Enteric Bacteriology	MDL Enteric Laboratory, California Department of Public Health
Microscopy	Antony van Leeuwenhoek
Molecular techniques	Rosalind Franklin
Mycobacteriology	Robert Koch
Mycology	Selman Waksman Sir Alexander Fleming
Serology	Paul Ehrlich

such as those described here will help microbiology students learn about their chosen field. They can also serve as a historical record. Looking forward, one wonders how the laboratory will be transformed in the near and distant future. If tools and implements that have been used in the lab for hundreds of years, such as petri dishes, test tubes, and even microscopes (Fig. 6), ever become obsolete or supplanted completely by machines and automation, these models will exist to show the evolution of the microbiology laboratory.

ACKNOWLEDGMENTS

The author would like to acknowledge Susan Perry-Hinkle, Terry Harville, Theresa Dudley and Deb Jackson for their assistance in the production of the models. The author declares that there are no conflicts of interest.

REFERENCES

1. Lee FG. 1952. Legal medicine at Harvard University. *J Crim L Criminology & Police Sci* 42(5):674–678.
2. Tamari F, Bonney KM, Polizzotto K. 2015. Prop demonstrations in biology lectures facilitate student learning and performance. *J Microbiol Biol Educ* 16(1):6–12.
3. Vallery-Radot R. 1916. *The life of Pasteur*. Doubleday, Page & Co., New York, NY.
4. Oren A. 2015. Teaching microbiology to undergraduate students in the humanities and the social sciences. *FEMS Microbiol Lett* 362(19):2–20.
5. Anonymous. 2010. Hans and Zacharias Jansen: A complete microscope history. *History-of-the-microscope.org*, UK. <http://www.history-of-the-microscope.org/hans-and-zacharias-jansen-microscope-history.php>.
6. Bordenave G. 2003. Review: on the shoulders of giants. Louis Pasteur (1822–1895). *Microbes Infect* 5:553–560.
7. Munch R. 2003. Review: on the shoulders of giants. Robert Koch. *Microbes Infect* 5:69–74.
8. Jay V. 2001. The legacy of Robert Koch. *Arch Pathol Lab Med* 125:1148–1149.
9. Kimsey P. 2005. Cutting-edge science underpins labs. *APHL Minute* 2:2.